



DEPARTMENT OF THE AIR FORCE  
59TH MEDICAL WING (AETC)  
JOINT BASE SAN ANTONIO - LACKLAND TEXAS



18 JULY 2017

MEMORANDUM FOR 59RSQ  
ATTN: LIEM T MANSFIELD

FROM: 59 MDW/SGVU

SUBJECT: Professional Presentation Approval

1. Your paper, entitled **Blast Injury of the Lower Extremities: From the Battlefield to the Home Front** presented at/published to **American Society of Emergency Radiology Annual Meeting, Toronto, Canada 6-9 September 2017** in accordance with MDWI 41-108, has been approved and assigned local file #**17276**.
2. Pertinent biographic information (name of author(s) title, etc.) has been entered into our computer file. Please advise us (by phone or mail) that your presentation was given. At that time, we will need the date (month, day and year) along with the location of your presentation. It is important to update this information so that we can provide quality support for you, your department, and the Medical Center commander. This information is used to document the scholarly activities of our professional staff and students, which is an essential component of Wilford Hall Ambulatory Surgical Center (WHASC) internship and residency programs.
3. Please know that if you are a Graduate Health Sciences Education student and your department has told you they cannot fund your publication, the 59th Clinical Research Division may pay for your basic journal publishing charges (to include costs for tables and black and white photos). We cannot pay for reprints. If you are a 59 MDW staff member, we can forward your request for funds to the designated Wing POC at the Chief Scientist's Office, Ms. Alice Houy, office phone: 210-292-8029; email address: [alice.houy.civ@mail.mil](mailto:alice.houy.civ@mail.mil).
4. Congratulations, and thank you for your efforts and time. Your contributions are vital to the medical mission. We look forward to assisting you in your future publication/presentation efforts.

LINDA STEEL-GOODWIN, Col, USAF, BSC  
Director, Clinical Investigations & Research Support



# PROCESSING OF PROFESSIONAL MEDICAL RESEARCH/TECHNICAL PUBLICATIONS/PRESENTATIONS

## INSTRUCTIONS

### USE ONLY THE MOST CURRENT 59 MDW FORM 3039 LOCATED ON AF E-PUBLISHING

1. The author must complete page two of this form:
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  - b. In Section 2, there may be funding available for journal costs, if your department is not paying for figures, tables or photographs for your publication. Please state "YES" or "NO" in Section 2 of the form, if you need publication funding support.
2. Print your name, rank/grade, sign and date the form in the author's signature block or use an electronic signature.
3. Attach a copy of the 59 MDW IRB or IACUC approval letter for the research related study. If this is a technical publication/presentation, state the type (e.g. case report, QA/QI study, program evaluation study, informational report/briefing, etc.) in the "Protocol Title" box.
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## **Blast Injury of the Extremities: From the Battlefield to the Home Front**

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## **Disclosure Statements**

- The authors received no financial support or incentive in the creation of this educational exhibit.
- The view(s) expressed herein are those of the authors and do not reflect the official policy or positions of Brooke Army Medical Center, the U.S. Army Medical Department, the U.S. Army Office of the Surgeon General, the Department of the Army, the Department of the Air Force, the Department of Defense, or the U.S. Government.

## **Acknowledgment**

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## **Objectives**

- To understand effects of explosion
- To review mechanism of injury and injury patterns in blast injuries
- To understand role of radiology in evaluation of acute injuries from improvised explosive devices (IED)
- To illustrate mounted and dismounted complex blast injuries

## **Sources of Blast Injury**

- **Military combat operations**
  - Conventional weapons
  - Landmines
  - Improvised explosive devices (IEDs)

## **Sources of Blast Injury**

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- **Acts of terrorism**



## Acts of Terrorism



## Sources of Blast Injury

- Military combat operations
  - Conventional weapons
  - Land mines
  - Improvised explosive devices (IEDs)
- Acts of terrorism
- Industrial accidents
  - Coal mines
  - Fertilizer and chemical plants
  - Fireworks factories

## Industrial Accidents

West Texas fertilizer company explosion



Deepwater horizon explosion



## Definition

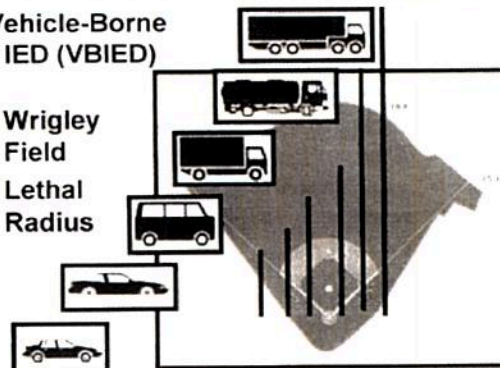
- I.E.D. is abbreviation for Improvised Explosive Devices
- Types:
  - Package or object IED
  - Personnel-borne IED (suicide bomber)
  - Vehicle-borne IED (car or truck bomb)
  - Bomb-rigged house

## Vehicle-Borne IED (VBIED)

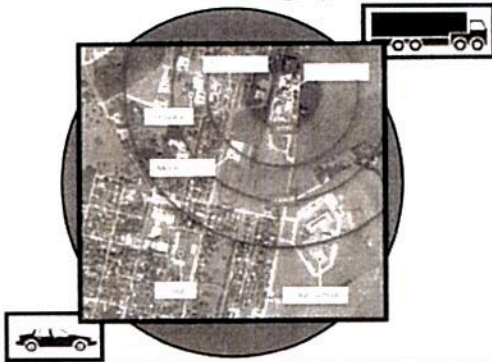
ATF	Vehicle Description	Minimum Explosive Quantity (Pounds)	Leak of Air (Meters)	Minimum Distance (Meters)	Falling Glass (Meters)
	Compact Sedan	4.3 pounds 2.27 Kilograms	100 Feet 30 Meters	1,500 Feet 457 Meters	1,200 Feet 366 Meters
	Full Size Sedan	7.1 pounds 3.2 Kilograms	125 Feet 38 Meters	1,750 Feet 534 Meters	1,750 Feet 534 Meters
	Passenger van (12 seats)	4,000 Pounds 1,818 Kilograms	200 Feet 61 Meters	2,750 Feet 838 Meters	2,750 Feet 838 Meters
	Small Box Truck (14,000 lbs)	75,000 Pounds 34,019 Kilograms	300 Feet 91 Meters	3,750 Feet 1,143 Meters	3,750 Feet 1,143 Meters
	Medium Box Truck (26,000 lbs)	150,000 Pounds 68,039 Kilograms	480 Feet 147 Meters	6,500 Feet 1,981 Meters	6,500 Feet 1,981 Meters
	Large Truck (40,000 lbs)	250,000 Pounds 113,400 Kilograms	600 Feet 183 Meters	7,000 Feet 2,134 Meters	7,000 Feet 2,134 Meters

## Vehicle-Borne IED (VBIED)

- Wrigley Field
- Lethal Radius



### Lethal Radius vs. Wrigley Field x 4



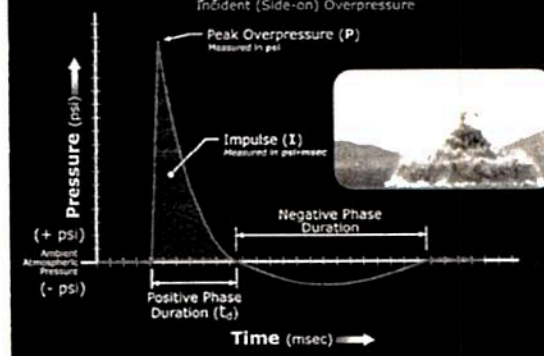
### Blast Injury

- Explosion is rapid chemical conversion of solid or liquid into gas with resultant energy release
- Two types of explosives
  - High-order explosives
  - Low-order explosives

### Hurricane Katrina



### Typical Blast Wave



### High-Order Explosives

- TNT, C-4, Semtex, nitroglycerin, dynamite, and ammonium nitrate fuel oil
- Detonate quickly, generating heat and loud noise, filling space with high pressure gases in 1/1000th second, and producing *supersonic* over pressurization shock wave
- "blast wave" (positive wave) moves in all directions, exerting pressures up to 700 tons
- Shock waves possess quality of brisance (shattering effect)

### Low-Order Explosives

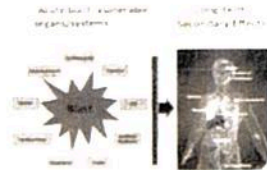
- Pipe bombs, gunpowder, Molotov cocktails, pure petroleum-based bombs
- Produce *subsonic* explosion without over pressurization shock wave
- Energy released relatively slowly and burns by a process of deflagration

## Effects of Explosives

- Blast pressure wave
- Fragmentation effect
- Blast wind
- Incendiary thermal effect
- Secondary blast pressure effects
- Ground and water shocks

## Mechanisms of injury and injury patterns in blast injury

- Specific injury patterns
- Life-threatening, multisystem or multi-dimensional, injuries



System	Injury or Condition
<b>Auditory</b>	TM rupture, ossicular disruption, cochlear damage, foreign body
<b>Face</b>	Perforated globe, foreign body, air embolism, fractures
<b>Respiratory</b>	Blast lung, hemothorax, pneumothorax, pulmonary contusion and hemorrhage, A-V fistulas (source of air embolism), airway epithelial damage, aspiration pneumonia, sepsis
<b>Gastrointestinal</b>	Bowel perforation, hemorrhage, ruptured liver or spleen, sepsis, mesenteric ischemia from air embolism
<b>Circulatory</b>	Cardiac contusion, myocardial infarction from air embolism, shock, vasovagal hypotension, peripheral vascular injury, air embolism-induced injury
<b>CNS</b>	Concussion, closed and open brain injury, stroke, spinal cord injury, air embolism-induced injury
<b>Genitourinary</b>	Renal contusion or laceration, acute renal failure due to rhabdomyolysis, hypotension, and hypovolemia, penile laceration, testicular rupture
<b>Extremity</b>	Traumatic amputation, fractures, crush injuries, compartment syndrome, burns, lacerations, acute arterial occlusion, air embolism-induced injury

From: Centers for Disease Control and Prevention. <http://www.bt.cdc.gov/terrorism/bioexplosion.asp>

## Factors Affecting Injuries

- Composition and type of bomb
- Delivery method
- Distance between victim and blast
- Location of blast, open or closed space
- Surrounding environmental barriers or hazards

## Location of Blast

- Explosions in closed spaces or that result in structural collapse have higher mortality and injury rates
- 1 out of 4 victims died immediately in *structural collapse*
- 1 of 12 in *confined space* bombings
- 1 in 25 in *open air* bombings
- Bus bombings resulted in highest mortality rate

## Reflected blast wave





## Reflected blast wave

	Open air explosion	Bas explosion
Mortality	8%	49%
Survivor mean ISS	4	18
Primary blast injury	34%	78%

Enderson DC, et al. Primary blast injuries: bas versus open air bombings: a comparative study of injuries in survivors of open air versus confined space explosions. J Trauma 1986; 31: 1030-5

## Types of Blast Injuries

- Primary
- Secondary
- Tertiary
- Quaternary
- Quinary

## Primary Blast Injuries

- Direct result of over pressurization wave's impact on body
- Occur mainly to gas-filled organs: auditory, pulmonary, & GI systems
- Injuries result from spalling, implosion, inertia, and extreme pressure differential at body surfaces causing stress wave that reproduces in underlying tissues
- Spalling occurs when shock wave travels from one medium to another of lesser density, such as from tissue fluid to air, resulting in waves in first medium that lead to macroscopic and microscopic tears at interface of 2 mediums

## Primary Blast Injury



## Secondary Blast Injuries

- Results from flying debris and bomb fragments "fragmentation effect" leading to penetrating ballistic or blunt force injuries



## Tertiary Blast Injuries

- Result of individuals being thrown by blast wind
- Victims may tumble along ground or be thrown through air and strike other objects (walls, cars, fences, ground) with resultant blunt or penetrating trauma



### Quaternary Blast Injuries

- Defined as any explosion-related injury or illness not due to any of the above, such as burns and inhalational injuries, exacerbation of underlying chronic conditions



### Quinary Blast Injuries

- Due to toxic materials absorbed by body from blast resulting in hemodynamic problems

### Injury Pattern

- Structural collapse victims sustained more inhalational and crush injuries (secondary and quaternary injuries) and fewer primary blast injuries
- Confined space bombings result in more primary and quaternary blast injuries
- Open air bombings led to higher rates of ballistic soft tissue injuries or more secondary blast injuries

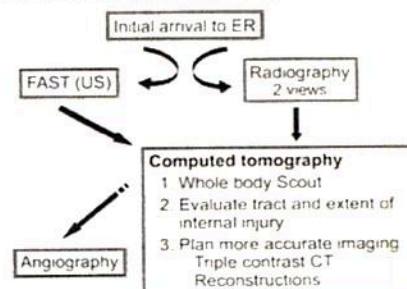
### Bombing Victims Had

- Higher injury severity scores, ISS > 16, 30% vs 10% for other trauma
- Increased immediate mortality, as high as 29% for closed space bombing
- Greater in-hospital mortality rate, 6.2% vs 3% for other trauma
- More frequent need for surgical intervention: orthopedic, longer hospital stays, greater use of intensive, younger age groups
- 53% requiring surgical procedures
- 23% requiring ICU stay
- 20% having hospital length of stay > 14 days
- Higher hospital resource utilization than victims of other trauma

### Causes of Death

- Multiple injuries 39%
- Head and chest injuries 21%
- Complete disruption of bodies 14%
- Head injuries 12%
- Chest injuries 11%

### Role of Radiology Department in Evaluation of Victims of IED





### Acute Setting

- Rapid mobilization of bedside radiography and sonography units in ED
- Imaging: X-ray, FAST, CT, angiography
- Direct verbal communication with health care providers
- Stability of PACS?
- Rapid interpretation of radiological exams which accompany patient upon transfer

### Radiological Evaluation in Acute Setting

- AP chest and pelvis radiographs
  - Limited by one view
  - Additional radiographs on basis of sites of penetrated wounds
  - Triage and/or guide CT, particularly when metallic fragments are identified
- FAST to detect presence of peritoneal fluid

### Radiological Evaluation in Acute Setting

- CT is very important imaging technique
- Radiologist stationed at every CT console
  - To aid in planning best protocol
  - To give real-time interpretations of exams
- Whole-body scout image (AP & LAT) may depict additional unsuspected sites of shrapnel not detected on X-ray

### CT Protocol

- Non-contrast
  - Head and face, 1 mm axial slice
  - Sagittal and coronal reformatted images
- Contrast
  - From circle of Willis through pelvis
  - Lower extremities as clinically indicated
  - Discuss with trauma team to establish inferior extent of scan coverage

### Radiological Evaluation in Acute Setting

- Indications for angiography
  - Limb ischemia
  - Clinical suspicion of vascular injury
  - Proximity of shrapnel to major vessels

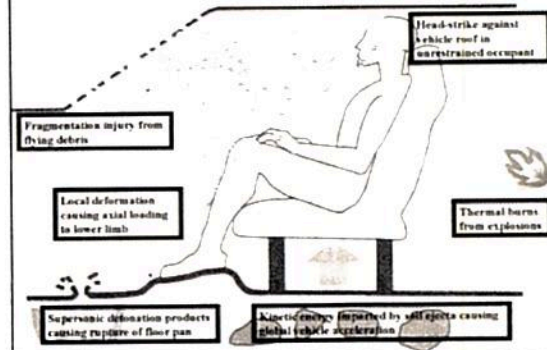
### Secondary Blast Injury



### Package Type IED Flashlight



### Mounted Blast Injury Pattern



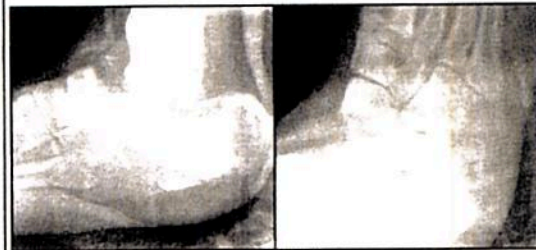
### Mounted Blast Injury Pattern



The initial impact absorbed by the sitting occupant is through the *calcanei* and *pelvis*.

Image courtesy of Dr. Brian Nagel

### Hx: 28 y.o. M s/p IED injury



Lateral and oblique radiographs of ankle show comminuted fractures of talus and calcaneus with dislocation of Chopart and talocalcaneal joints.

### Mounted Blast Injury



### Mounted Blast Injury Pattern



The force of the impact continues to travel upward leading to high energy fractures of both the *axial* and *appendicular* skeleton.

Image courtesy of Dr. Brian Nagel



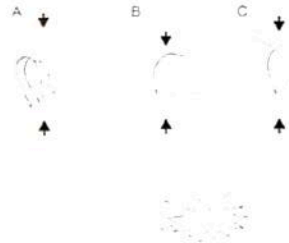
### Mounted Blast Injury Pattern



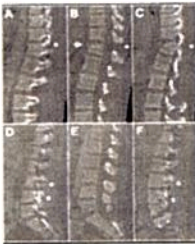
The occupant travels upward and then strikes the ceiling with the skull leading to *skull* and *cervical spine* fractures.

Image courtesy of Dr. Brian Knapf

### Possible Mechanisms of Chance Fracture



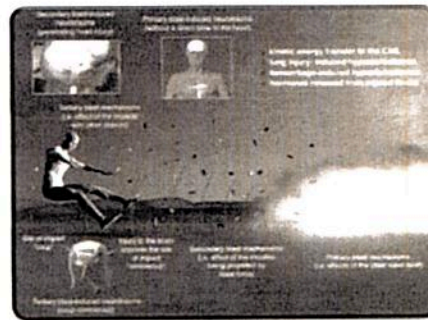
### Mounted Complex Blast Injury Flexion-Distraction Fractures



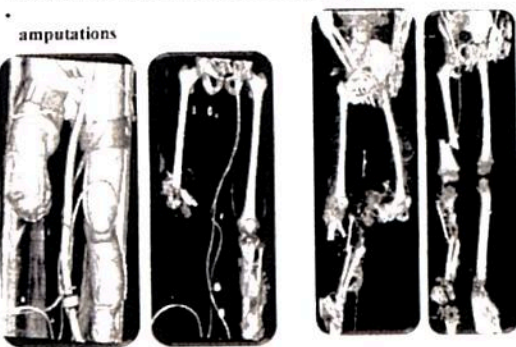
- 12 men
- 16 thoracolumbar fractures
  - fractures (38%)
  - 7 compression fractures (44%)
  - 3 burst fractures (19%)
  - 3 patients with multiple fractures (25%)

Ragel BT et al. Fractures of the thoracolumbar spine sustained by soldiers in vehicles attacked by improvised explosive devices. Spine 2009; 15:2400-5

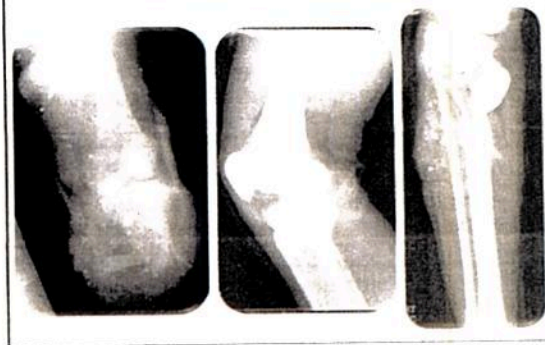
### Dismounted Blast Injury Pattern

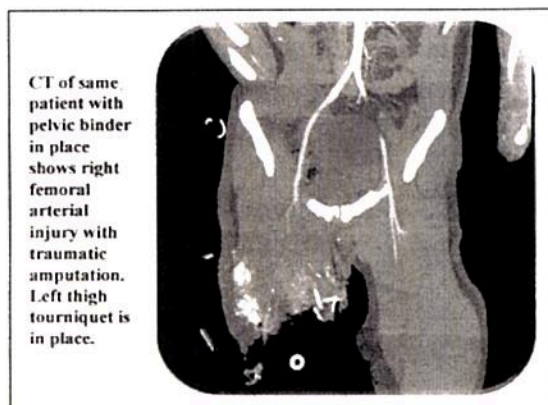
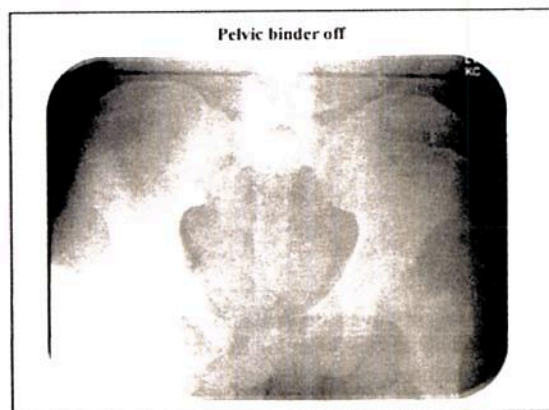
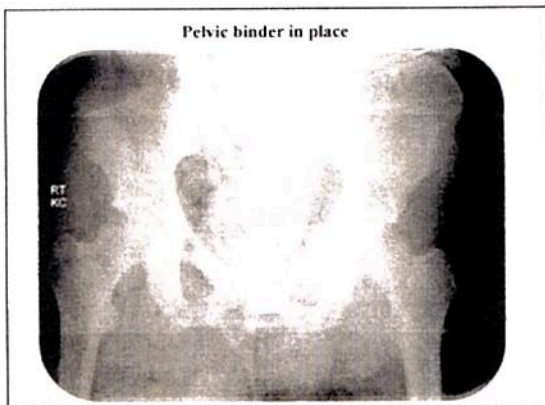


### Dismounted Blast Injury



### Dismounted Blast Injury





### Orthopedic Injuries

- Traumatic amputations have poor prognosis
  - 11% of fatalities had traumatic amputation
  - Survival rate of 1% for victims with traumatic amputation
- Madrid bombing, 36% had shrapnel wounds and 18% had fractures
- Oklahoma City bombing, 35% of survivors had musculoskeletal injuries, with 37% of these victims having multiple fractures

### Orthopedic Injuries

- Clinicians should be aware that
  - Fragments may NOT travel in straight lines
  - Significant internal injuries may result from small entrance wounds
  - \_\_\_\_\_ should be suspected in any victim with *thighs, perineum, or buttocks*
  - Any *hematoma* may indicate *vascular injury*
  - *Compartment syndrome* and *rhabdomyolysis* can be complications of musculoskeletal injuries, especially in setting of structural collapse and/or prolonged extrication

### Conclusion

- Blast injury is fundamentally different from typical blunt or penetrating trauma
- Blast injury victims do have specific injury patterns
- They often have life-threatening *multisystem* or *multidimensional* injuries
- Radiologists play critical role in assessment of their injuries





**DEPARTMENT OF THE AIR FORCE  
AIR EDUCATION AND TRAINING COMMAND**



6 July 2017

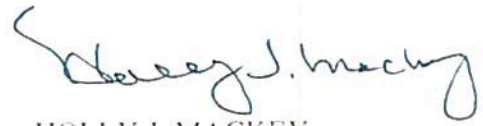
MEMORANDUM FOR 59 MDW/PUBLICATIONS AND PRESENTATIONS MANAGER

FROM: 502 ISG/JA

SUBJECT: Conference Presentation – American Society of Emergency Radiology Annual Meeting

1. A request for a legal review of a presentation titled "Blast Injury of the Lower Extremities from the Battlefield to the Homefront" was submitted by the 59 MDW Publications and Presentation Manager for review. The presentation will be given by Liem Mansfield, GS-15, 59 RSQ at the American Society of Emergency Radiology Annual Meeting in Toronto, Canada on 6-9 September 2017. There is no information regarding whether it has been submitted to Public Affairs for review. It is submitted for legal review because the presentation will be given at a meeting held outside the country. There are no apparent conflicts of interest issues that would prohibit presentation of this material at a meeting held by a professional association. The fact the meeting will be held in Canada does not prohibit presentation of the material at this meeting.
2. FACTS: Liem Mansfield, GS-15 plans to make a presentation titled "Blast Injury of the Lower Extremities from the Battlefield to the Homefront" at the American Society of Emergency Radiology Annual Meeting in Toronto, Canada on 6-9 September 2017.
3. LAWS AND REGULATIONS: DoD 5500.07-R, Joint Ethics Regulation (JER), section 3-307 lays out rules governing "Teaching, Speaking and Writing." If the presentation will "deal in significant part with any ongoing or announced policy, program or operation" of the Air Force, the presenter is required to include a disclaimer that states the "views presented are those of the speaker or author and do not necessarily represent the views of DoD or its Components."
4. ANALYSIS: Although the presentation does not "deal in significant part with any ongoing or announced policy, program or operation" of the Air Force, the presentation does address information obtained during the presenter's government employment. Additionally, his affiliation is included on the title slide. Mr. Mansfield included the required disclaimer that the views presented are those of the speaker and do not necessarily represent the views of DoD or its Components. Public Affairs must review the presentation and approve it. There is no prohibition to presentation of this material at this professional meeting simply because it will be held in Canada.
5. CONCLUSIONS: The presentation provided for review included the disclaimer required by the JER. There are no apparent conflicts of interest or issues that would prohibit publication.

6. If you have any questions, please call me at 671-5789.

A handwritten signature in black ink, appearing to read "Holly J. Mackey". The signature is fluid and cursive, with a large loop at the end.

HOLLY J. MACKEY  
Attorney-Advisor

I concur.

A handwritten signature in black ink, appearing to read "Melanie McGhee". The signature is fluid and cursive, with a large loop at the end.

MELANIE MCGHEE  
Chief, Civil Law